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David Taylor Research Center

Bethesda, Maryland 20084-5000

EFFECT OF INCREASED OUTER HULL SETBACK
ON RESISTANCE FOR THE O'NEILL HULL FORM
REPRESENTED BY DTRC MODELS 5355-1, -2

by
James E. Wood

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A second series of resistance experiments were performed on a model representing the O'Neill Hull Form. These experiments were to investigate the resistance benefits of increasing outer hull setback distances over previously examined conditions. In addition, experiments were done with a second set of outer hulls at three different setback configurations. Experimental results show that the increased outer hull setback distances yield decreased resistance consistently above 24 knots full scale when the model is fitted with either set of outer hulls. (Small Waterplane area hulls.) jed.

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

iv

NOTATION

C_A	Correlation Allowance
C_F	Frictional Resistance Coefficient
C_R	Residuary Resistance Coefficient
F_n	Froude Number
g	Acceleration due to gravity
L	Length
P_E	Effective Power
S	Wetted Surface
V_M	Model Speed
V_S	Ship Speed

ABBREVIATIONS

DTRC	David Taylor Research Center
IED	Independent Exploratory Development Program
OHF	O'Neill Hull Form
SPAWAR	Space and Naval Warfare Systems Command
SWATH	Small Waterplane Area Twin Hull

ENGLISH/SI EQUIVALENTS

ENGLISH	SI
1 foot	0.3048 m (meters)
1 foot per second	0.3048 m/s (meters per second)
1 horsepower	0.7457 kw (kilowatts)
1 knot	0.5144 m/s (meters per second)
1 long ton (2240 lbs)	1.0160 t (tonnes)

v

ABSTRACT

A second series of resistance experiments were performed
on a model representing the O'Neill Hull Form. These exp-
eriments were to investigate the resistance benefits of increasing
outer hull setback distances over previously examined cond-
itions. In addition, experiments were done with a second set of
outer hulls at three different setback configurations. Exp-
erimental results show that the increased outer hull setback
distances yield decreased resistance consistently above 24 knots
full scale when the model is fitted with either set of outer hulls.

ADMINISTRATIVE INFORMATION

INTRODUCTION

Analytical and experimental predictions [1]* of the resistance characteristics of the O'Neill Hull Form

(OHF) have indicated promise for its use by the U. S. Navy. The O'Neill Hull Form has potential for

exhibiting the favorable characteristics typical of small waterplane area ships, including excellent stability in

most seaway conditions. Current small waterplane area ships are of the SWATH (small waterplane area twin

hull) type. These twin hulled ships typically have significantly more wetted surface area than monohull ships

of equal tonnage. As a consequence they tend to have higher frictional resistance. In addition, SWATH ships

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* References are listed on page 6.

1

tend to have shorter waterline lengths, generally resulting in higher wavemaking resistance at the higher speeds. The OHF is composed of what is in effect one hull of a SWATH and two widely spaced, slender outer hulls. This tri-hull configuration has shown potential for reduced wavemaking resistance over an equivalent twin hulled ship.

The SWATH Ship Development Office of the Systems Integration Department (Code 1235) requested that the Ship Hydromechanics Department conduct additional resistance experiments under the IED program at DTRC. These experiments were to investigate further the effects of longitudinal location of the outer hulls on resistance. Of specific interest was the performance when the outer hulls were set back far enough to be located entirely within the Kelvin wake generated by the bow of the center hull.

The set back distance is the longitudinal distance from the forward tip of the center hull to the forward tip of the outer hull. This distance affects the phasing between the waves generated by the nose and tail sections of the center hull and the waves generated by the nose and tail sections of the outer hulls. According to thin ship theory, the nose and tail sections of the struts and lower hulls contribute to wavemaking resistance with no contribution from the parallel mid-body sections. As the ship moves through the water it generates transverse waves having the same celerity as the ship speed. The length of the transverse waves increase as ship speed squared. A divergent wave system is also generated whose wave lengths also increase as ship speed squared. As the outer hulls are moved aft a point is reached where the wave systems of the outer hulls falls entirely within the Kelvin wake generated by the center hull. The Kelvin wake is defined as a wave pattern made up of transverse and divergent wave systems. The net Kelvin wave pattern for a ship consists of a complex interaction of the wave systems generated by the entire hull geometry; but the main effects spring from the prominent hull slope changes occurring at the bow, shoulders, and stern. The principal wave zone lies within a wedge shaped region emanating from the stem area of the hull, with the half angle of 19 degrees 28 minutes. When the outer hulls lie entirely within the Kelvin wedge (roughly) of the main hull, there is increased possibility for favorable interactions between the outer hull wave systems and those generated by the center hull.

2

MODEL

DTRC Model 5355-1,2 representing the 4260 long ton (4328 tonne) O'Neill Hull Form Concept was constructed to a linear scale ratio of 25.23. The principal dimensions are presented in Table 1. Photographs of the OHF are shown in Figure 1.

Model 5355-1 represents the OHF with its original set of outer hulls. Model 5355-2 represents the concept with a different, shorter pair of outer hulls. Each variation of the OHF consists of a pair of outer hulls attached to the upper hull of Model 5355 at an angle of 10 degrees outboard from the vertical. The outer hulls are removable allowing them to be positioned in several different longitudinal locations, each representing a different experimental setback configuration. The two sets of outer hulls have the same waterplane area at the design waterline. They differ only in length, maximum thickness, and wetted surface. No other appendages or control surfaces were attached to the model.

Tripwires of 0.025 inch (0.635mm) diameter were attached to the model to stimulate turbulence. They were placed five percent of the hull length aft of the leading edge of the center strut and each outer hull and five percent aft of the nose of the lower hull. The tripwires were secured to the model with uniformly spaced wire staples.

EXPERIMENTS

Experiments were performed on Model 5355-1 to represent two configurations - with the original outer hulls in the aft position and with the original outer hulls in the far aft position. Experiments with Model 5355-2 represented three configurations - with the new outer hulls in the far aft position, with the new outer hulls in the aft position, and with the new outer hulls in the baseline position. The experimental program is listed in Table 2.

The OHF experiments were performed with the model rigidly attached to the floating girder of DTRC Towing Carriage One. Standard DTRC procedures were used for resistance experiments on surface ship models.

3

The model experimental data was extrapolated to full scale conditions representing calm, deep sea water at 59 degrees Fahrenheit (15 degrees Celsius). A correlation allowance of $C_A = 0.0005$ was used in conjunction with the 1957 ITTC ship-model correlation line. No allowance was made for still air drag.

The frictional resistance calculations for both model and ship were based on the length reynolds number of each component of the ship (lower hull, center hull, and outer hulls). Laminar flow was assumed to exist on the model from the leading edge of the tip of each component back to the location of the tripwire. In this region the Blasius line was used to determine the frictional resistance coefficient. Aft of the tripwire to the trailing edge of each component of the hull, turbulent flow was assumed and the ITTC ship-model correlation line was applied.

The residuary resistance was calculated by subtracting the sum of the frictional resistance of each component and the parasitic drag of the tripwires from the total measured resistance of the model. The parasitic drag was calculated using a computer program documented in Reference 2.

RESULTS AND CONCLUSIONS

Effective power predictions for all configurations that were examined are summarized in Tables 3 through 7. Comparisons of residuary resistance coefficients for the various configurations of Models 5355-1 and 5355-2 are illustrated in Figures 2 and 3 respectively. Figure 4 presents the full scale effective power prediction for the OHF with the original outer hulls. Figure 5 presents the full scale effective power prediction for the OHF with the new outer hulls. Table 8 and Figure 6 show the residuary resistance of the aft and far aft positions of Model 5355-2 relative to the baseline position. The wetted surface area for Model 5355-1 is different from that of Model 5355-2. The figures make comparisons between different configurations of the ship that have the same wetted surface area.

Results predict that on Model 5355-1 (representing the original outer hulls) there is better resistance performance over a greater portion of the speed range when the outer hulls are in the far aft setback position. With the outer hulls in this position resistance is higher from 20 to 22 knots but is lower at the other speeds - consistently so at speeds above 25 knots.

4

Test results also predict that on Model 5355-2 (representing the new outer hulls) resistance is lower over a greater portion of the speed range when the outer hulls are in the far aft setback position. Resistance is higher between 18 and 22 knots, but only two thirds as high above 24 knots.

For both variations of the O'Neill Hull Form the lowest resistance was predicted when the outer hulls were in the far aft setback position. Of all cases examined, Model 5355-2 (representing the shorter, thicker outer hulls) in the far aft position exhibited the best resistance performance.

Thus far all resistance testing of the OHF has been done using a captive model. This has been appropriate for comparison of various outer hull setback distances. Once an outer hull configuration is chosen, future resistance experiments should be done using a model that is free to sink and trim. This will allow for a more realistic prediction of full scale resistance characteristics. In addition, lower bodies of revolution have been envisioned for the outer hulls. These should also be included in future experiments in order to assess their merit.

5

REFERENCES

1. Wood, J.E., "Effect Of The Longitudinal Location Of A Pair Of Outer Hulls On Resistance For The 4300 Ton O'Neill Hull Form Concept (OHF) Ship Represented By DTNSRDC Model 5355-1", Ship Performance Department Departmental Report 1147-01, August 1985.

2. Hansen, A.G., "A Computer Program For Evaluation Of The Effective Power Of Submarines From Model Experiment Data", Scientex Report TSC-18-1, March 1981.
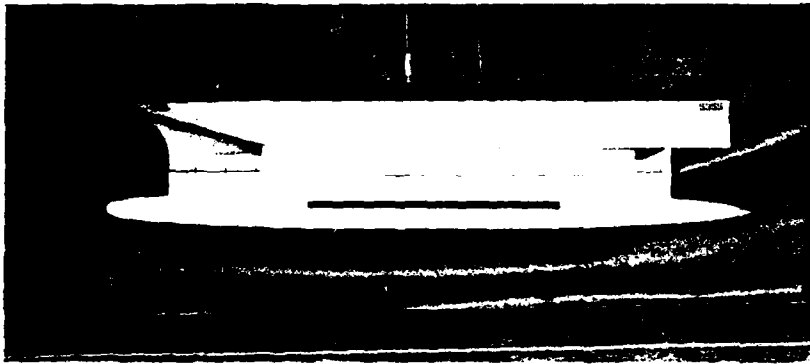
New Outer Hulls In Baseline Position
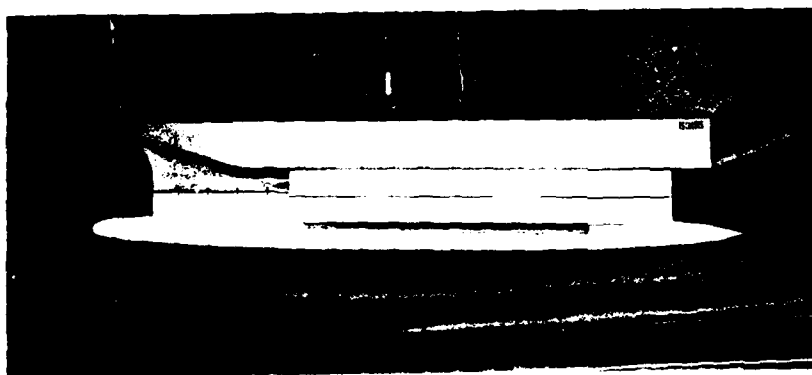
New Outer Hulls In Aft Position
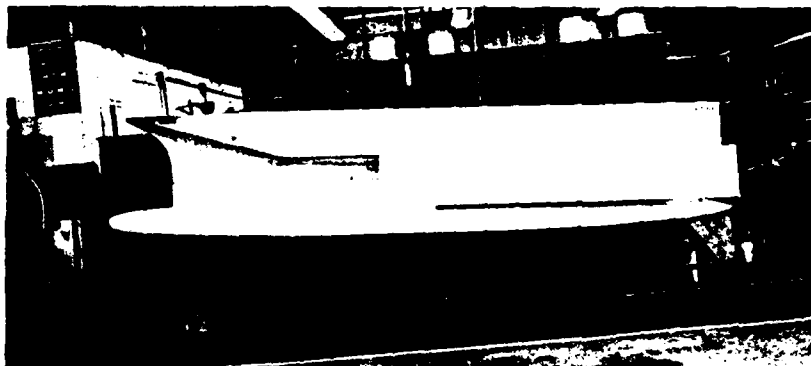
New Outer Hulls In Far Aft Position

FIGURE 1 - PHOTOGRAPHS OF THE O'NEILL HULL FORM

7

RESIDUARY RESISTANCE COEFFICIENTS FOR OHF
DETERMINED FROM EXPERIMENTS WITH MODEL 5355-1
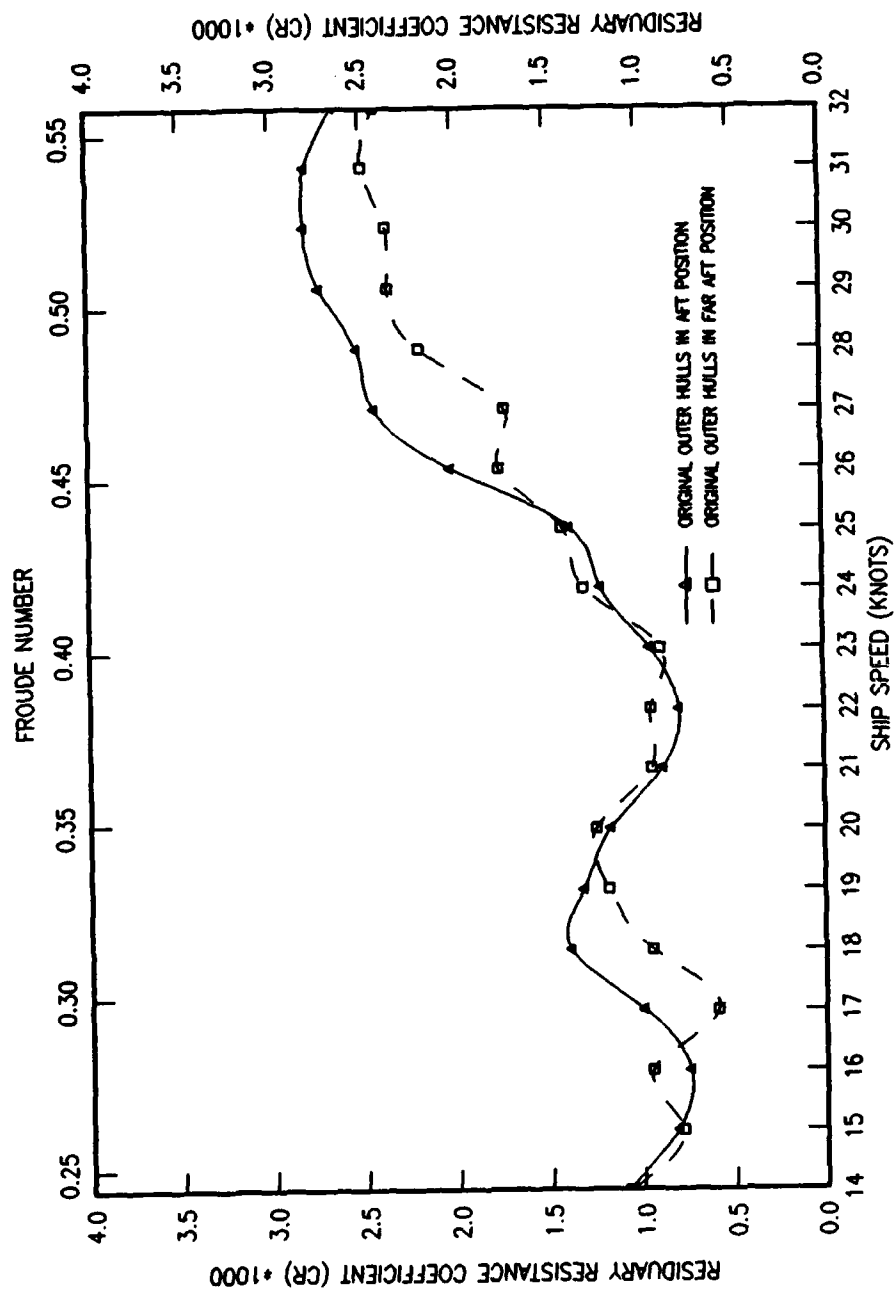
FIGURE 2 - RESIDUARY RESISTANCE FOR THE OHF WITH ORIGINAL OUTER HULLS

8

RESIDUARY RESISTANCE COEFFICIENTS FOR OHF
DETERMINED FROM EXPERIMENTS WITH MODEL 5355-2
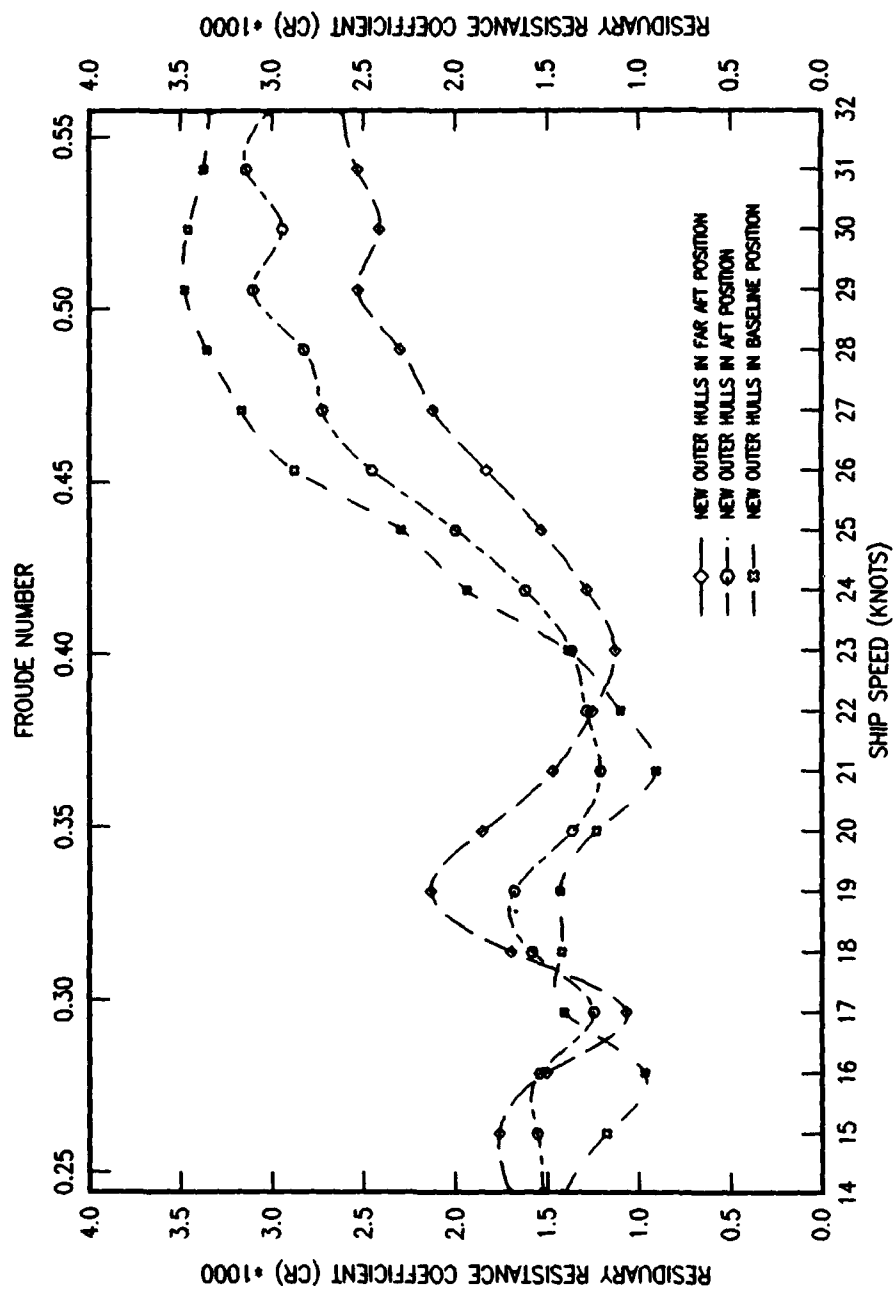
FIGURE 3 - RESIDUARY RESISTANCE FOR THE OHF WITH NEW OUTER HULLS

9

EFFECTIVE POWER PREDICTION FOR OHF
DISPLACEMENT 4260 LONG TONS (4328 TONNES)
MODEL HELD AT FIXED ZERO TRIM
CORRELATION ALLOWANCE .0005   ITTC FRICTION LINE
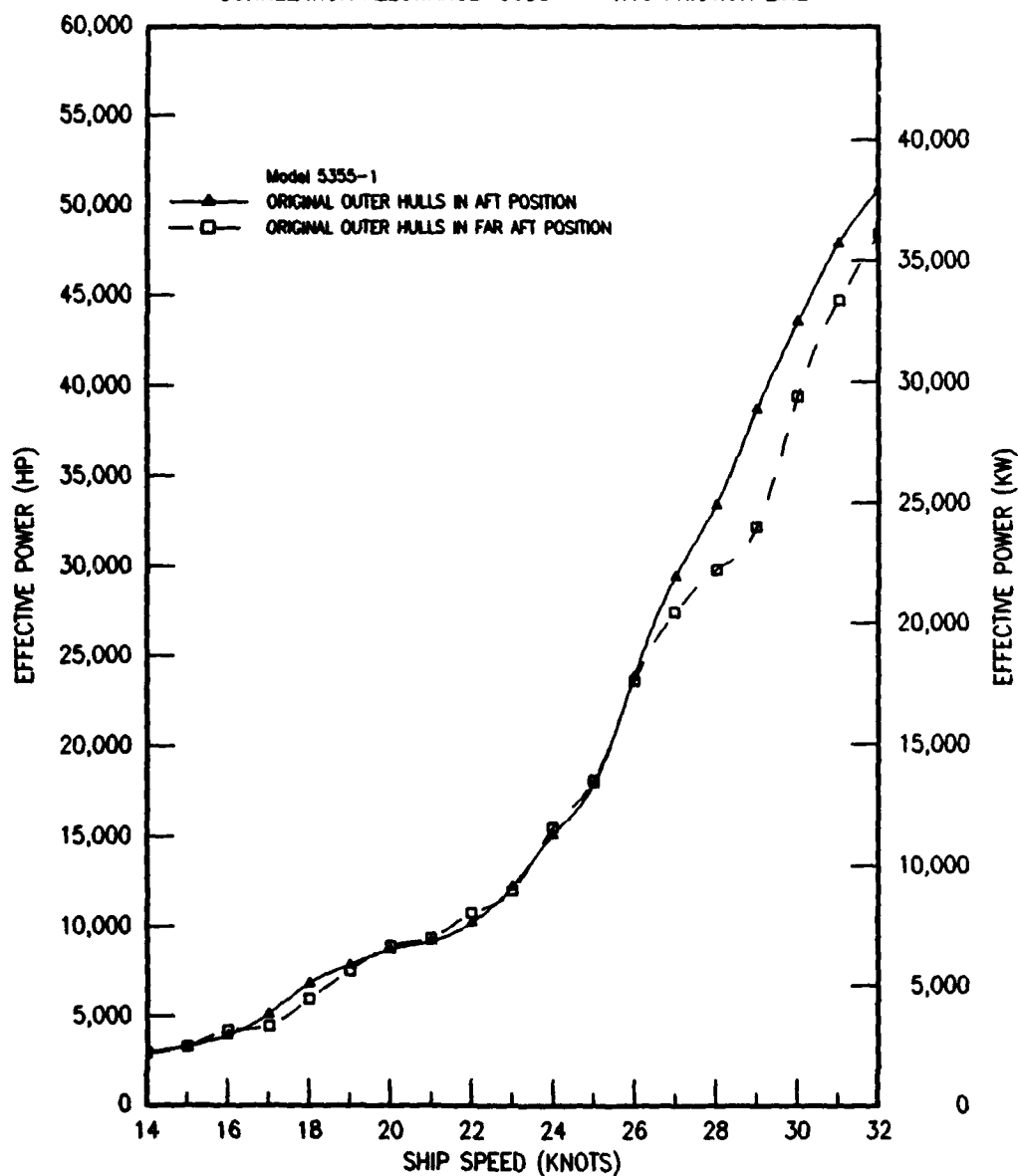
FIGURE 4 - EFFECTIVE POWER FOR THE OHF WITH ORIGINAL OUTER HULLS

10

EFFECTIVE POWER PREDICTION FOR OHF

DISPLACEMENT 4260 LONG TONS (4328 TONNES)
MODEL HELD AT FIXED ZERO TRIM
CORRELATION ALLOWANCE .0005   ITTC FRICTION LINE

Model 5355-2
—◇— NEW OUTER HULLS IN FAR AFT POSITION
—◇— NEW OUTER HULLS IN AFT POSITION
—□— NEW OUTER HULLS IN BASELINE POSITION
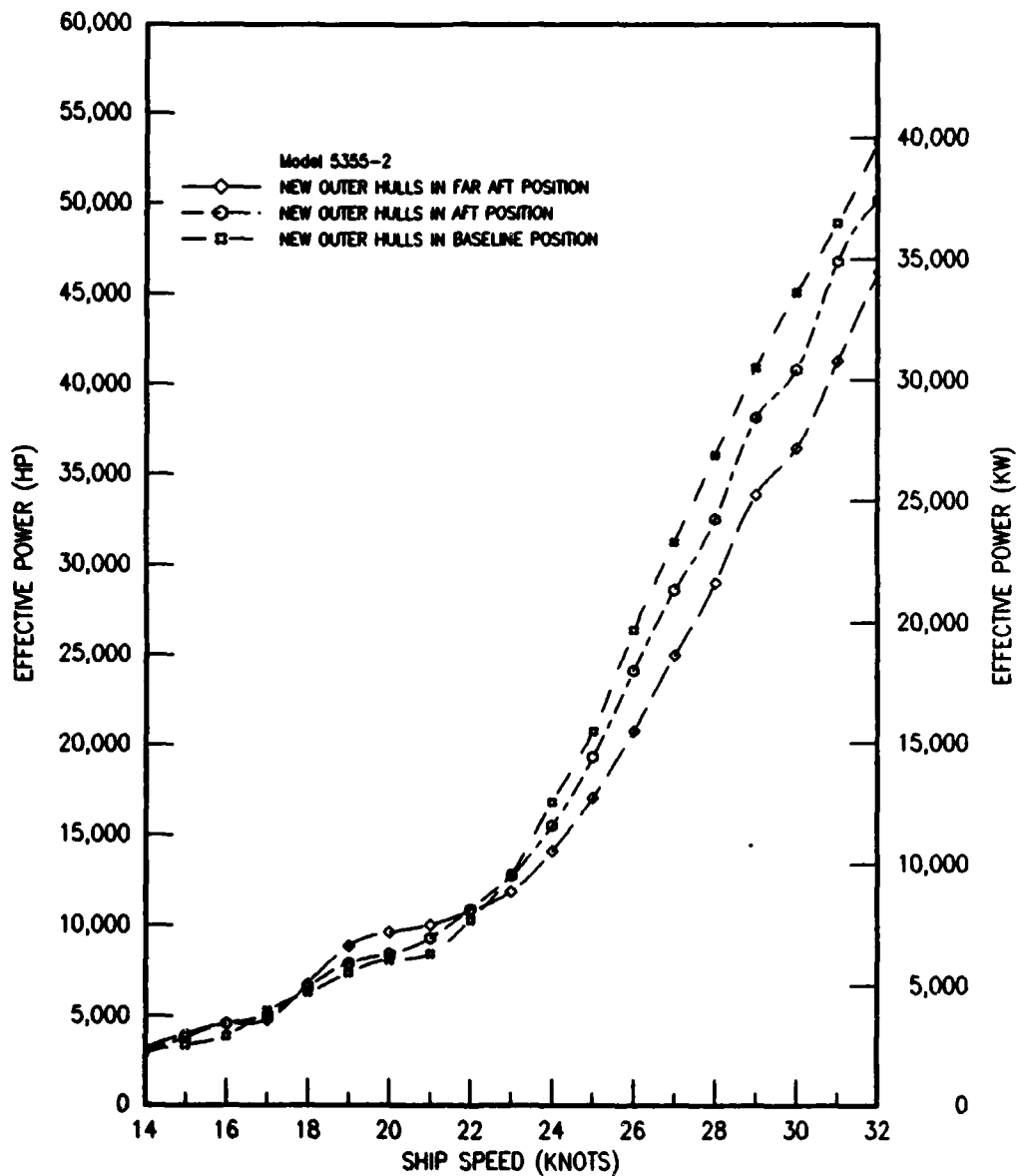
FIGURE 5 — EFFECTIVE POWER FOR THE OHF WITH NEW OUTER HULLS

11

EFFECT OF OUTER HULL SETBACK DISTANCE ON CR RELATIVE TO BASELINE
FOR MODEL 5355-2 (NEW OUTER HULLS)
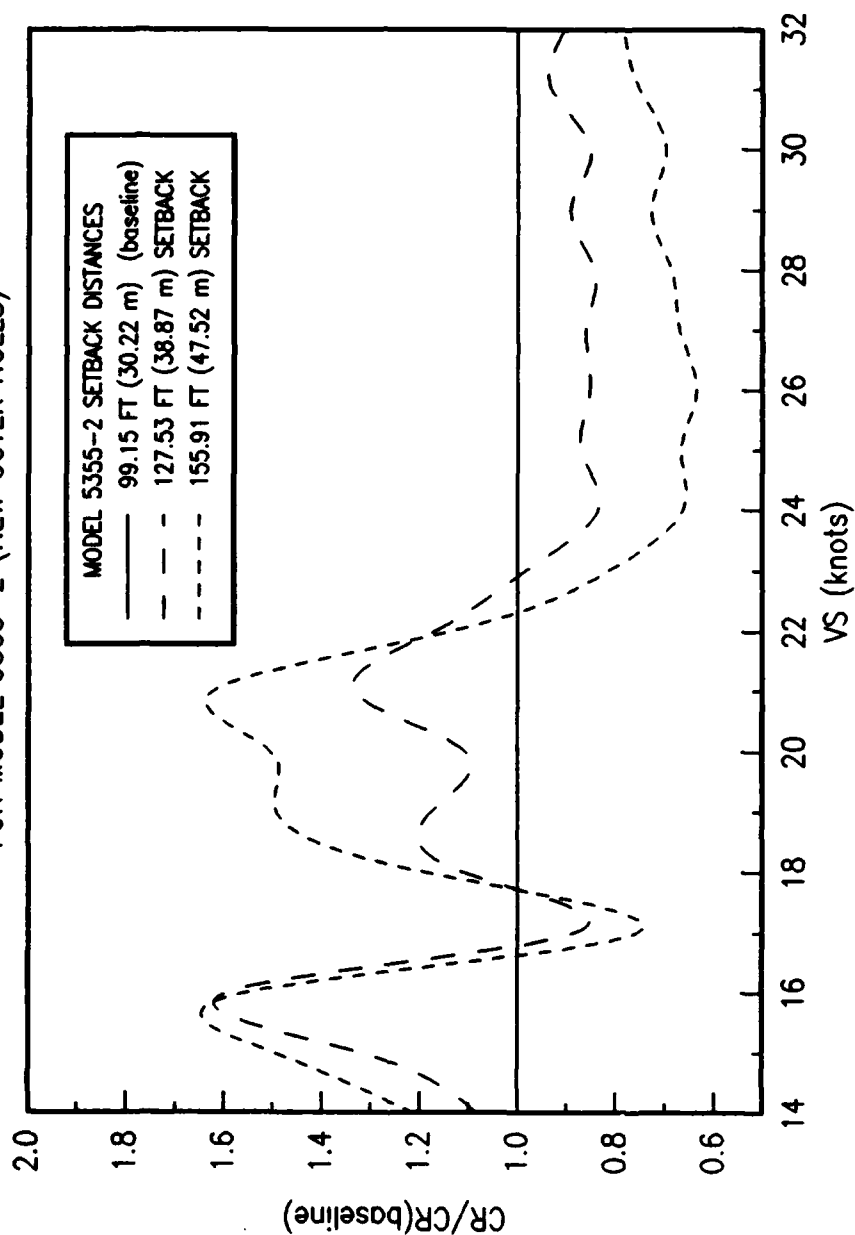
FIGURE 6 – EFFECT OF INCREASED OUTER HULL SETBACK FOR MODEL 5355-2

12

TABLE 1 - THE O'NEILL HULL FORM CONCEPT DIMENSIONS

SCALE RATIO = 25.23   DISPLACEMENT = 4260 long tons (4328 tonnes)

DIMENSION	SHIP	MODEL
Draft	32.168 ft (9.805 m)	1.275 ft (.389 m)
Effective Length	291.31 ft (88.79 m)	11.55 ft (3.519 m)
Lower Hull Length	354.99 ft (108.20 m)	14.07 ft (4.289 m)
Center Strut Length	280.05 ft (85.359 m)	11.099 ft (3.383 m)
Upper Hull Length	322.69 ft (98.356 m)	12.789 ft (3.898 m)
Max. Lower Hull Diameter	21.45 ft (6.538 m)	0.85 ft (0.259 m)
Ctr. Strut Maximum Width	9.84 ft (2.999 m)	0.39 ft (0.119)
Maximum Beam Overall	106.0 ft (32.309 m)	4.20 ft (1.280 m)
Lower Hull Wetted Surface	16607.05 ft^2 (1542.85 m^2)	26.09 ft^2 (2.42 m^2)
Center Strut Wetted Surface	7410.45 ft^2 (688.45 m^2)	11.64 ft^2 (1.08 m^2)

With Original Outer Hulls   (Model 5355-1)

	SHIP	MODEL
Total Wetted Surface	38488.22 ft^2 (3575.67 m^2)	60.464 ft^2 (5.62 m^2)
Outer Hull Length	224.0 ft (68.28 m)	8.878 ft (2.706 m)
Outer Hull Maximum Width	5.5 ft (1.676 m)	0.218 ft (.066 m)
Single Outer Hull WS	7235.36 ft^2 (672.19 m^2)	11.366 ft^2 (1.06 m^2)

With New Outer Hulls   (Model 5355-2)

	SHIP	MODEL
Total Wetted Surface	35072.16 ft^2 (3258.31 m^2)	55.097 ft^2 (5.12 m^2)
Outer Hull Length	190 ft (57.912 m)	7.531 ft (2.295 m)
Outer Hull Maximum Width	6.6 ft (2.012 m)	0.262 ft (.080 m)
Single Outer Hull WS	5527.25 ft^2 (513.50 m^2)	8.683 ft^2 (0.081 m^2)

TABLE 2 - MODEL 5355-1,-2 (OHF) RESISTANCE EXPERIMENTS

Experiment Number	Model Configuration
9	Original Outer Hulls in Aft Position (Set back 93.53 ft (28.51 m) from nose of body)
10	Original Outer Hulls in Far Aft Position (Set back 121.91 ft (37.16 m) from nose of body)
11	New Outer Hulls in Far Aft Position (Set back 155.91 ft (47.52 m) from nose of body)
12	New Outer Hulls in Aft Position (Set back 127.53 ft (38.87 m) from nose of body)
13	New Outer Hulls in Baseline Position (Set back 99.15 ft (30.22 m) from nose of body)

14

TABLE 3 - EFFECTIVE POWER PREDICTION FOR OHF AS DETERMINED FROM EXPERIMENTS WITH MODEL 5355-1 (ORIGINAL OUTER HULLS IN AFT POSITION)

SHIP SPEED (KNOTS)	FN	C_R $*10^3$	PE (HP)	PE (KW)	C_F (MODEL) $*10^3$	C_F (SHIP) $*10^3$
14	0.244	1.093	2990	2230	3.379	1.661
15	0.262	0.816	3350	2500	3.337	1.647
16	0.279	0.747	3950	2940	3.297	1.633
17	0.296	0.992	5120	3820	3.261	1.620
18	0.314	1.390	6830	5090	3.228	1.609
19	0.331	1.316	7840	5850	3.196	1.598
20	0.349	1.167	8720	6500	3.168	1.587
21	0.366	0.881	9170	6840	3.140	1.577
22	0.384	0.792	10200	7610	3.114	1.568
23	0.401	0.946	12250	9130	3.090	1.559
24	0.418	1.212	15100	11260	3.066	1.551
25	0.436	1.378	17900	13350	3.045	1.544
26	0.453	2.021	23880	17800	3.024	1.536
27	0.471	2.434	29410	21930	3.004	1.529
28	0.488	2.524	33420	24920	2.985	1.522
29	0.506	2.727	38730	28880	2.967	1.515
30	0.523	2.808	43550	32480	2.950	1.509
31	0.540	2.798	47880	35710	2.933	1.503
32	0.558	2.645	50940	37980	2.917	1.497

15

TABLE 4 - EFFECTIVE POWER PREDICTION FOR OHF AS DETERMINED FROM EXPERIMENTS WITH MODEL 5355-1 (ORIGINAL OUTER HULLS IN FAR AFT POSITION)

SHIP SPEED (KNOTS)	FN	C_R *10^3	PE (HP)	PE (KW)	C_F (MODEL) *10^3	C_F (SHIP) *10^3
14	0.244	1.076	2970	2220	3.379	1.662
15	0.262	0.788	3320	2470	3.336	1.646
16	0.279	0.950	4220	3140	3.298	1.633
17	0.296	0.587	4460	3330	3.261	1.620
18	0.314	0.948	5970	4450	3.228	1.609
19	0.331	1.180	7530	5610	3.196	1.597
20	0.349	1.245	8920	6650	3.167	1.587
21	0.366	0.942	9360	6980	3.140	1.577
22	0.384	0.947	10750	8020	3.113	1.568
23	0.401	0.886	12000	8950	3.089	1.559
24	0.418	1.302	15510	11570	3.067	1.552
25	0.436	1.419	18120	13520	3.044	1.544
26	0.453	1.759	23600	17600	3.024	1.536
27	0.471	1.725	27400	20430	3.004	1.529
28	0.488	2.185	29800	22220	2.985	1.522
29	0.506	2.351	32180	24000	2.967	1.515
30	0.523	2.362	39440	29410	2.950	1.509
31	0.540	2.488	44740	33360	2.933	1.503
32	0.558	2.415	48410	36100	2.917	1.497

TABLE 5 - EFFECTIVE POWER PREDICTION FOR OHF AS DETERMINED FROM EXPERIMENTS WITH MODEL 5355-2 (NEW OUTER HULLS IN FAR AFT POSITION)

SHIP SPEED (KNOTS)	FN	C_R *10^3	PE (HP)	PE (KW)	C_F (MODEL) *10^3	C_F (SHIP) *10^3
14	0.244	1.705	3240	2420	3.399	1.668
15	0.262	1.761	4030	3010	3.356	1.653
16	0.279	1.502	4540	3390	3.317	1.639
17	0.296	1.066	4790	3570	3.281	1.627
18	0.314	1.696	6780	5060	3.247	1.615
19	0.331	2.133	8870	6610	3.215	1.604
20	0.349	1.852	9630	7180	3.186	1.594
21	0.366	1.469	10040	7490	3.159	1.584
22	0.384	1.248	10800	8050	3.132	1.574
23	0.401	1.132	11870	8850	3.108	1.565
24	0.418	1.284	14090	10510	3.085	1.558
25	0.436	1.532	17070	12730	3.062	1.550
26	0.453	1.829	20760	15480	3.041	1.542
27	0.471	2.120	24950	18600	3.021	1.535
28	0.488	2.299	28990	21620	3.002	1.528
29	0.506	2.530	33860	25250	2.984	1.521
30	0.523	2.411	36460	27190	2.966	1.515
31	0.540	2.533	41280	30790	2.950	1.508
32	0.558	2.618	46200	34450	2.934	1.503

TABLE 6 - EFFECTIVE POWER PREDICTION FOR OHF AS DETERMINED FROM EXPERIMENTS WITH MODEL 5355-2 (NEW OUTER HULLS IN AFT POSITION)

SHIP SPEED (KNOTS)	FN	C_R $*10^3$	PE (HP)	PE (KW)	C_F (MODEL) $*10^3$	C_F (SHIP) $*10^3$
14	0.244	1.524	3090	2310	3.400	1.668
15	0.262	1.553	3820	2850	3.357	1.653
16	0.279	1.540	4590	3420	3.317	1.639
17	0.296	1.245	5060	3770	3.281	1.627
18	0.314	1.582	6580	4910	3.247	1.615
19	0.331	1.679	7920	5900	3.215	1.604
20	0.349	1.362	8450	6300	3.186	1.594
21	0.366	1.208	9300	6940	3.158	1.584
22	0.384	1.285	10920	8140	3.132	1.575
23	0.401	1.367	12740	9500	3.107	1.565
24	0.418	1.618	15500	11560	3.084	1.557
25	0.436	2.000	19310	14400	3.062	1.550
26	0.453	2.453	24110	17980	3.041	1.542
27	0.471	2.724	28590	21320	3.021	1.534
28	0.488	2.825	32520	24250	3.003	1.527
29	0.506	3.102	38120	28430	2.984	1.521
30	0.523	2.941	40820	30440	2.967	1.515
31	0.540	3.140	46790	34890	2.950	1.509
32	0.558	3.016	50190	37420	2.933	1.503

18

TABLE 7 - EFFECTIVE POWER PREDICTION FOR OHF AS DETERMINED FROM EXPERIMENTS WITH MODEL 5355-2 (NEW OUTER HULLS IN BASELINE POSITION)

SHIP SPEED (KNOTS)	FN	C_R *10^3	PE (HP)	PE (KW)	C_F (MODEL) *10^3	C_F (SHIP) *10^3
14	0.244	1.410	3000	2230	3.399	1.668
15	0.262	1.176	3430	2560	3.357	1.653
16	0.279	0.969	3890	2900	3.317	1.640
17	0.296	1.406	5290	3950	3.281	1.627
18	0.314	1.421	6290	4690	3.247	1.615
19	0.331	1.429	7390	5510	3.216	1.603
20	0.349	1.231	8110	6050	3.186	1.593
21	0.366	0.906	8450	6300	3.158	1.584
22	0.384	1.099	10310	7690	3.133	1.574
23	0.401	1.387	12810	9560	3.107	1.565
24	0.418	1.936	16840	12560	3.084	1.558
25	0.436	2.297	20730	15460	3.062	1.549
26	0.453	2.876	26370	19660	3.041	1.542
27	0.471	3.166	31240	23290	3.022	1.535
28	0.488	3.354	36050	26880	3.002	1.528
29	0.506	3.476	40920	30510	2.983	1.521
30	0.523	3.456	45070	33610	2.966	1.515
31	0.540	3.371	48910	36470	2.950	1.509
32	0.558	3.341	53430	39840	2.933	1.503

TABLE 8 - EFFECT OF OUTER HULL SETBACK DISTANCE ON C_R RELATIVE TO BASELINE POSITION ON MODEL 5355-2

SHIP SPEED (knots)	$\dfrac{C_R(\text{aft})}{C_R(\text{baseline})}$	$\dfrac{C_R(\text{far aft})}{C_R(\text{baseline})}$
14	1.081	1.209
15	1.321	1.497
16	1.589	1.550
17	0.885	0.758
18	1.113	1.194
19	1.175	1.493
20	1.106	1.504
21	1.333	1.621
22	1.169	1.136
23	0.986	0.816
24	0.836	0.663
25	0.871	0.667
26	0.852	0.635
27	0.860	0.670
28	0.842	0.685
29	0.892	0.728
30	0.851	0.698
31	0.931	0.751
32	0.903	0.784

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A second series of resistance experiments were performed on a model representing the O'Neill Hull Form. These experiments were to investigate the resistance benefits of increasing outer hull setback distances over previously examined conditions. In addition, experiments were done with a second set of outer hulls at three different setback configurations. Experimental results show that the increased outer hull setback distances yield decreased resistance consistently above 24 knots full scale when the model is fitted with either set of outer hulls. (Small Waterplane area hulls)

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